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DIAGNOSIS OF STATOR INTER-TURN SHORT CIRCUIT IN DTC INDUCTION MOTOR DRIVES

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ABSTRACT

Faults in the stator windings of three-phase induction machines are recognized to play a major role in the failures that occur during the machines life span. The machines (or motors) which were fed by inverters tend to worsen its condition, due to the fast switching of the power semiconductors used by the inverters in which promotes voltage stresses. After a period of time the machines will be affected by the degradation of the stator turns insulation which will eventually lead to winding short circuits. By diagnosing the stator faults in DTC induction motor drives, we can then determine the failures which the information could be used to construct an artificial intelligence system that can help monitor and pin-point the source of motor failure. Thus overcoming the problems is possible and further development of the machines can be done in the near future.

ABSTRAK

Kerosakan dalam gulungan stator motor induksi tiga fasa memainkan peranan utama dalam kegagalan yang berlaku selama jangka hayat mesin. Motor-motor yang dijana oleh inverter cenderung untuk mengalami kerosakan kerana peralihan cepat oleh semikonduktor kuasa yang digunakan oleh inverter yang mempromosikan penekankan voltan. Selepas tempoh masa tertentu, motor akan dipengaruhi oleh degradasi stator yang akhirnya akan mengarah pada litar pintas. Dengan mendiagnosis kerosakan dalam stator DTC motor induksi, kita boleh menentukan kerosakan di mana maklumat yang telah dikumpulkan boleh digunapakai untuk membina sebuah sistem kecerdasan buatan yang dapat membantu memantau dan menunjukkan sumber kegagalan motor. Dengan ini masalah-masalah yang timbul dapat diatasi dan pengembangan lanjut enjin boleh dilakukan dalam waktu dekat.

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CHAPTER 1

INTRODUCTION

Chapter Overview:

The title of this project is Diagnosis of Stator Inter Turn Short Circuit in DTC Induction Motors. The monitoring and fault detection of DTC induction machines have moved in recent years from traditional techniques to artificial intelligence (AI) techniques. Such techniques require a minimum configuration intelligence since no detailed analysis of the fault mechanism is necessary, nor is any modeling of the system required. When an AI technique is used, fault detection and evaluation can be accomplished without a human expert.

Induction motors play an important role in manufacturing environments, therefore this type of machine is mainly considered and many diagnostic procedures are proposed from industries. Some work has also been done on converter-fed induction motor drives in order to realize a fault-tolerant drive avoiding shutdown if the load conditions permit faults and failures.

This project is divided into 3 different tasks because it is mainly to collect data, analyze and acknowledge the behavior of the motor condition and then determine the causes of the fault occurrence. The main steps of a diagnostic procedure can be classified as follows:

1) Data Collection
2) Data Manipulation
3) Data Implementation

Project Background

Artificial intelligence techniques have proved their ability in detection of incipient faults in electrical machines. In this project, the fault diagnosis of three phase induction motors is studied using models and neural networks have been used in the fault diagnosis of induction motors using Radial Basis Neural Network (RBNN) in MATLAB.

Problem Statement

The increased in demand has greatly improved the approach of fault detection in induction motors. Nowadays artificial intelligence is implemented to improve traditional techniques, where the results can be obtained instantaneously after it analyzes the input data of the motor.

Artificial intelligence approached can easily do difficult analysis such as pattern recognition and nonlinear system identification and control. In this project, Radial Basis

Neural Network is used to train data and analyzes the condition of the motor. The neural network is then would be used as a tool to investigate the conditions of the winding by comparing the actual data to the database (offline monitoring).

Objectives

The Diagnosis of Stator Inter Turn Short Circuit in DTC Induction Motors is developed with the listed objectives below:

- To develop and create a new reliable technique by using artificial intelligence to detect stator inter turn short circuit in DTC induction motor.
- To apply basic knowledge on Artificial Neural Network Tools in MATLAB.
- To train radial basis function to produce output whether there are no fault or stator fault for three-phase induction motor.

Project Scopes

There are several scopes for the project:

- Radial Basis Neural Network (RBNN) approach will be used for Artificial Neural Network training and test.
- This project is use to detect faults in three phase DTC induction motors only. It is the most popular induction motor in industry.
- Limited to detect stator inter turn faults only.

Thesis Outline

This thesis consists of five chapters. In the first chapter, this chapter discussed the overall idea of this project including objectives of project, problem statement, the scope of this project and summary of this thesis.

Chapter 2 discussed more on theory and literature review that have been done. It is well discusses about the ANN, basic concept of the fault in induction motor, Radial Basis Function network and parameters related to this project.

Chapter 3 described briefly the methodology of the data extraction, fault evaluation and ANN development for this project. The figures, tables and extra information are aided into this chapter to be the benchmark thesis in development of Radial Basis Function Neural Network in detection of stator inter turn fault in the DTC induction motor.

Chapter 4 presents a discussion of the implementation, result and analysis of the whole project. This chapter also explains the reasons of some failure.

Chapter 5 provides the conclusions of the project. There are also several suggestions that can be used for future implementation or upgrading for this project.

CHAPTER 2

LITERATURE REVIEW

Chapter Overview:

This chapter includes all the paper works and related research as well as the studies regards to this project. The chapter includes all important studies which have been done previously by other research work. The related works have been referred carefully since some of the knowledge and suggestions from the previous work can be implemented for this project.

Literature review was an ongoing process throughout the whole process of the project. It is very essential to refer to the variety of sources in order to gain more knowledge and skills to complete this project. These sources include reference books, thesis, journals and also the materials obtained from internet.

2.1 MOTOR

2.1.1 Induction Motors

'An induction motor (IM) is a type of asynchronous AC motor where power is supplied to the rotating device by means of electromagnetic induction. Another commonly used name is squirrel cage motor because the rotor bars with short circuit rings resemble a squirrel cage (hamster wheel). ' [8]

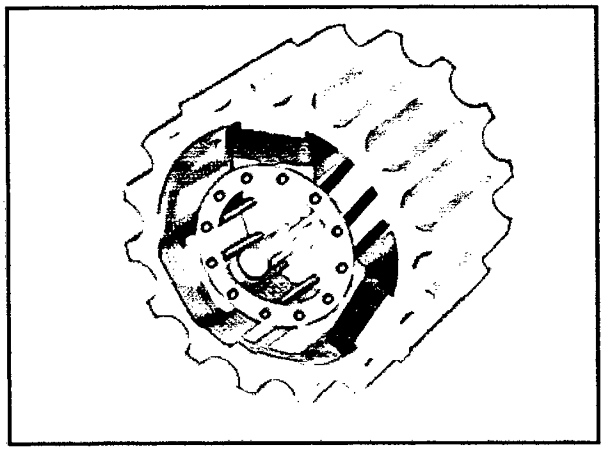

Figure 1 Induction Motor

'Induction motors are now the preferred choice for industrial motors due to their rugged construction, absence of brushes (which are required in most DC motors) and — thanks to modern power electronics — the ability to control the speed of the motor.' [8]

'Three-phase, induction motors are the workhorse of industry. From cement plants to the power generation sector, passing by the pulp and paper industry, induction motors are the most common type of motors used in these industries. In addition, these motors usually perform critical tasks, where an unscheduled stop can cause high production and financial losses.

Statistical studies have demonstrated that common types of faults in three-phase induction motors are roll bearings damage, stator faults, both in the electric and magnetic circuit, air gap eccentricity, and rotor faults such as broken rotor bars. Therefore, a lot of works have been done in the last two decades for the development of adequate diagnostic techniques, able to detect these faults as soon as possible, in order to prevent major damages to the machine, thus decreasing downtime and the repair cost.

Although most of the diagnostic techniques were initially developed for line-connected motors, the high penetration rates of induction motor drives, particularly those drive systems based on vector controlled and direct torque controlled induction motors, have created new challenges and established new targets for the diagnostic system. The high harmonic content introduced in the current and voltage signals, as well as the existence of closed loops in the control system of these drives make the diagnostic process more complicated than ever. In these adverse conditions, most of the traditional diagnostic techniques that were effective for line-connected motors fail when dealing with induction motor drives. Other aspect that should be emphasized at this point is the use of different diagnostic techniques to diagnose different types of faults, as it appears that no technique is able to cope easily with all types of faults. Moreover, some of the diagnostic techniques proposed so far rely on a detailed knowledge about the motor, usually difficult to obtain when the motors are already installed and in operation'.[9]

2.2 CONTROLLER

2.2.1 Direct Torque Control (DTC)

'Direct torque control (DTC) is one method used in variable frequency drives to control the torque (and thus finally the speed) of three-phase AC electric motors. This involves calculating an estimate of the motor's magnetic flux and torque based on the measured voltage and current of the motor.' [6]

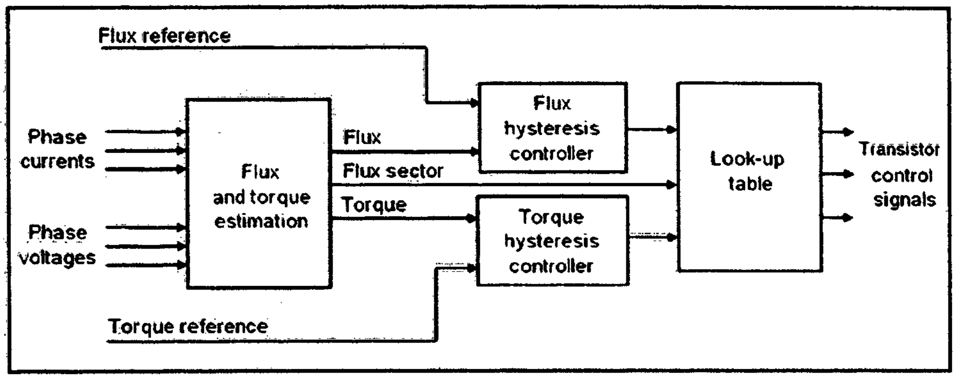

Figure 2 DTC Block Diagram

'Direct torque control is achieved by means of a selection table, the inputs of which are the torque error, the error in magnitude of the stator flux space vector, and the angle of the stator flux space vector. The magnitude error signal of the stator flux is discretized into two levels by means of a hysteresis comparator. The torque error signal is discretized into three levels by means of a three stage hysteresis comparator. The stator flux angle is discretized into six 60 degrees sections. The outputs of the selection table are the settings for the power switching devices of the inverter.' [2]

'Controllers based on direct torque control do not require a complex coordinate transform. The decoupling of the nonlinear ac motor structure is obtained by the use of on-off control, which can be related to the on-off operation of the inverter power switches. Similarly to field oriented control, the flux and the torque are either measured or estimated and used as feedback signals for the controller. However, as opposed to field oriented control, the states of the power switches are determined directly from the measured and the reference torque and flux signals' [2]

2.3 INDUCTION MOTOR FAULTS

Induction machine failure surveys have found the most common failure mechanisms in induction machines. These have been categorized according to the main components of a machine–stator related faults, rotor related faults, bearing related faults and other faults.

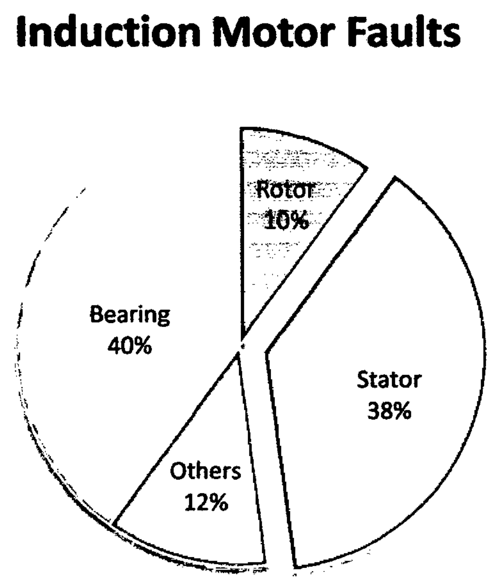

Figure 3 Induction Motor Faults

2.3.1 Stator Faults

'Almost 40% of all reported induction machine failures fall into this category. The stator winding consists of coils of insulated copper wire placed in the stator slots. Stator winding faults are often caused by insulation failure between two adjacent turns in a coil. This is called a turn-to-turn fault or shorted turn. The resultant induced currents produce extra heating and cause an imbalance in the magnetic field in the machine. If undetected, the local heating will cause further damage to the stator insulation until catastrophic failure occurs. The unbalanced magnetic field can also result in excessive vibration that can cause premature bearing failures.' [1]

Some of the most frequent causes of stator winding failures are:

- high stator core or winding temperatures,
- slack core lamination, slot wedges, and joints,
- loose bracing for end winding,
- contamination caused by oil, moisture, and dirt,
- short circuits,
- starting stresses,
- electrical discharges,
- leakage in the cooling systems

2.4 SENSOR SIGNALS

As the induction machine is highly symmetrical, the presence of any kind of fault in it affects its symmetry. This leads to a corresponding change in the interaction of flux between the stator and rotor, resulting in changes to the stator currents, voltages, magnetic field and machine vibration. Thus these signals can be used for on-line condition monitoring.

2.4.1 Vibration

Vibration monitoring is one of the oldest condition monitoring techniques and is widely used to detect mechanical faults such as bearing failures or mechanical imbalance. A piezo-electric transducer providing a voltage signal proportional to acceleration is often used. This acceleration signal can be integrated to give the velocity or position.

2.4.2 Stator Current

The stator current is usually measured using a clip-on Hall-effect current probe. It contains frequency components which can be related to a variety of faults such as mechanical and magnetic asymmetries, broken rotor bars and shorted turns in the stator windings. Most of the published research work in recent years has examined the use of the stator current for condition monitoring, particularly using frequency analysis.

2.4.3 Axial Magnetic Flux

The axial magnetic leakage flux of an induction machine is readily measured using a circular search coil which is placed on the non-drive (rear) end of the machine, concentric with the shaft. The search coil produces an output voltage which is proportional to the rate of change of the axial leakage flux. This signal contains many of the same frequency components which are present in the stator current. It is particularly useful for estimating the speed as it contains a strong component at the slip frequency.

2.4.4 Stator Voltage

This can be safely measured using a high frequency differential voltage probe or isolation amplifier. It has been used to calculate the instantaneous power, instantaneous torque and negative sequence impedance.

2.4.5 Other Techniques

Temperature sensors monitoring the bearings and stator windings have been traditionally used for condition monitoring. They provide a useful indication of machine overheating but offer limited fault diagnostic capability.

Partial discharge analysis is used for detecting stator insulation faults in higher voltage motors. It consists of detecting the low amplitude, ultrafast pulses (nS) produced by electric discharges in small voids in the insulation. Partial discharges occur even in healthy machines, however an increase in the amount of partial discharge activity can be associated with insulation degradation.

2.5 SIGNAL PROCESSING TECHNIQUE

Signal processing techniques are applied to the measured sensor signals in order to generate features or parameters (e.g. amplitudes of frequency components associated with faults) which are sensitive to the presence or absence of specific faults.

2.5.1 RMS

'Calculation of simple statistical parameters such as the overall root mean squared (RMS) value of a signal can give useful information. For instance, the RMS value of the vibration velocity is a convenient measure of the overall vibration severity. In the same way, the RMS value of the stator current provides a rough indication of the motor loading.'

2.5.2 Frequency Analysis

'Frequency analysis using the Fourier transform is the most common signal processing method used for online condition monitoring. This is because many mechanical and electrical faults produce signals whose frequencies can be determined from knowledge of motor parameters such as the number of poles. These fault signals appear in a variety of sensor signals including vibration, current and flux.' [1]

'The supplied current waveform and the phase current waveform are not sinusoid so that the frequency spectrum of the current is abundant. With the different control strategies, the current waveform and the harmonic component are different. Un-sinusoid waveform current could cause the electromagnetic interference.'

2.4.3 Other Frequency Analysis Methods

The Fourier transform used for conventional frequency analysis assumes that the frequency spectrum is not changing with respect to time over the sampling period. This assumption is not always valid, especially with mechanical loads which show considerable variation over time.

Time-frequency techniques overcome this issue by Current Spectrum (dB) dividing the signal into short time segments over which it is relatively constant, and computing the